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STREAM ASSIMILATIVE CAPACITY

- A GRAPHICAL PROCEDURE

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Ministry of the Environment
Ontario

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ONTARIO
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Stream Assimilative Capacity
A Graphical Procedure
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STREAM ASSIMILATIVE CAPACITY - A GRAPHICAL PROCEDURE

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PREFACE

The methodology presented in this manual is a simplified graphical approach to waste assimilation analysis. The analysis is structured so that water quality responses can be estimated with a minimum amount of information. This does not preclude the use of any available water quality and quantity data, available data should be scrutinized for use in the analysis.

Discretion is to be used when interpreting the results of the analysis especially with respect to treatment levels and projected water quality effects, they should be regarded only as engineering estimates and not as precise solutions. Much of the material presented in this manual was taken from "Simplified Mathematical Modelling of Water Quality", prepared by Hydroscience Inc. for the EPA, March 1971. It was revised and adapted to reflect the criteria and conditions for Ontario.

INTRODUCTION

Mathematical models are being used extensively to analyse water quality in rivers and streams, estuaries and impoundments. This report outlines the application of the dissolved oxygen model in a simplified manner to rivers and streams. In relating wastewater discharges to water quality in the receiving body, the water body is assumed to be one dimensional (i.e. longitudinal) and the basic geometry of the system is relatively simple. Only single point sources are considered, although distributed sources can be ~~only~~ approximated by a point source at its centre of gravity.

As with any type of waste loading assessment, some basic facts and knowledge of the subject are required. For example, it is important that the analyst has the resources available to calculate drought streamflows, measure or estimate upstream water quality conditons, determine maximum water temperatures, etc.

The method presented in this manual has definite advantages over other "arm-chair" assessment methods traditionally employed. It also has certain limitations that the analyst must take into consideration.

Advantages:

1. In-depth knowledge of dissolved oxygen balance equaitons, reaction rate coefficients, etc. is not required.

2. A computer or sophisticated desk-top calculator is not required.

3. With the appropriate input material at hand, calculations can be completed in a few minutes.

4. A wide variety of options can be quickly and easily tested.

Limitations:

1. The impact of aquatic floral photosynthesis and respiration, sludge demand, artificial aeration, etc. cannot be directly taken into account by this method.

2. A reasonably accurate knowledge of physical conditions of the stream (i.e. mean depth, velocity, bottom type, turbulence, etc.) is usually required and on occasions may necessitate a short reconnaissance field trip.

The report is presented in two sections together with an appendix. The first section outlines the technical data required for analysis, i.e. population, waste loads, treatment efficiencies, etc. Included are graphs and tables representing guidelines and ranges for the above mentioned parameters. The second section outlines the theory and development of the model together with worked examples to show how the nomograph is to be used.

The appendix discusses the reaction coefficients involved in the dissolved analysis in streams. The graphs included are based on actual field data and can be used where data is unavailable for the stream in question.

I TECHNICAL DATA REQUIRED FOR ANALYSIS

For a preliminary water quality analysis, of streams and rivers, the factors which determine the quantity of waste from treatment plant discharged to the stream, together with the geophysical characteristics of the stream are reviewed.

The quantity of waste depends on the size of the population, per capita waste quantities and the removal efficiency of the particular waste treatment process.

The geophysical features include the temperature, natural background water quality, structure and shape of the drainage system and the flow of the stream.

1. Waste Discharge

a. Population[1]- The design population Pd, is established by multiplying the present population Po, by the growth factor f_1, for that region:

$$Pd = f_1 Po \ldots\ldots \quad 1.1$$

[1] *In most cases the design population is given. Present population and future population predictions figures can be obtained from the Ministry of Treasury Economics and Intergovernmental Affairs or the Regional Municipality concerned.*

b. Per Capita Waste Flow and Quality - varies from municipality to municipality depending on the characteristics of the region, e.g. population, the extent of industrialization and the hydrological feature of the region. Table 1 presents some guidelines for per capita waste flows. A typical municipal waste is 150 gallons per capita/day with an ultimate carbonaceous BOD and nitrogenous BOD of about 0.26 and 0.16 pounds per capita day respectively.

The waste flow and mass rate of discharge are therefore:

$$q = f_2 \, Pd = f_2 \, f_1 \, Po \; \ldots\ldots \quad 1.2$$

where:

q = wastewater flow (usually MIGD)

f_2 = per capita flow (gallons/capita-day)

and:

$$I = f_3 \, Pd = f_3 \, f_1 \, Po \; \ldots\ldots \quad 1.3$$

where:

I = mass loading rate to treatment plant (pounds/day)

f_3 = per capita contribution (pounds/capita-day)

TABLE 1

PER CAPITA WASTE FLOWS AND QUALITY

	f_2 gallons / cap-day	Ultimate BOD lb/cap-day		Suspended Solids lb/cap-day	Nutrients lb/cap-day	
		BOD_c	BOD_n		Total N	Total P
Low	100	0.15	0.12	0.15	0.02	0.005
Average	150	0.26	0.16	0.30	0.04	0.01
High	225	0.40	0.23	0.45	0.05	0.018

TABLE II

ESTIMATED EFFICIENCY OF TREATMENT LEVELS

ULTIMATE OXYGEN DEMAND

Treatment Level	% Removal		#/Cap UOD Remaining		Total	f_4 Fraction UOD Remaining
	BOD_c	BOD_n	BOD_c	BOD_n		
1. Primary	60	10	0.104	0.144	0.248	0.59
2. Intermediate	80	15	0.052	0.136	0.188	0.45
3. Secondary	90	75	0.026	0.040	0.066	0.16
4. Advanced	95	95	0.013	0.008	0.021	0.05

c. <u>Treatment Efficiences and Residuals</u>

Treatment levels can be categorized into groups as follows:

1. Primary

   Systems employing screening and sedimentation, includes private and communal septic tanks (range 40-60% BOD_5 removal).

2. Intermediate

   Primary with phosphorus removal, some lagoon systems (range 60-80% BOD_5 removal).

3. Secondary

   Systems employing treatment such as conventional activated sludge, trickling filters and waste stabilization ponds with phosphorus removal (range 80-90% BOD_5 removal).

4. Advanced

   Systems employing treatment such as extended aeration (nitrification), contact stabilization, filtration and activated carbon (range 90-97% BOD_5 removal).

With these discrete treatment levels and the following assumptions, guidelines can be developed for overall treatment efficiency. Table II and III are based on the following assumptions:

a) 150 gallons/capita-day,

b) 0.26 pounds ultimate CBOD/capita-day,

c) 0.16 pounds ultimate NBOD/capita-day,

d) 0.01 pounds P/capita-day,

e) 0.04 pounds nitrogen/capita-day.

The efficiency guidelines in Tables II and III may be used to estimate the discharge waste load.

i.e.: $W = f_4 I = f_4 f_3 f_1 Po$ 1.4

where: W = mass rate of waste material discharged to the receiving water (pounds/day)

f_4 = residual fraction after treatment (Tables II and III).

TABLE III

ESTIMATED EFFICIENCY OF TREATMENT LEVELS

PHOSPHORUS AND TOTAL NITROGEN

Treatment Level	Phosphorus Fraction Removed	Phosphorus Residual	#P/ Cap/day Remaining	TKN Fraction Converted	TKN Residual	#TKN Cap/day Remaining
1. Primary	0.45	0.55	0.006	0.10	0.90	0.036
& P removal	0.80	0.20	0.002	0.10	0.90	0.036
2. Intermediate	0.80	0.20	0.002	0.15	0.85	0.034
3. Secondary	0.50	0.50	0.005	0.75	0.25	0.010
& P removal	0.80	0.20	0.002	0.75	0.25	0.010
4. Advance	$\geq$ 0.90	$\leq$ 0.10	$\leq$ 0.001	0.95	0.05	0.002

2. Drainage Basin Characteristics

a. Temperature - critical water quality conditions usually occur during the middle to late summer when the water temperature is high. The temperature affects the solubility of many substances as well as the rate coefficient of many reactions. In dissolved oxygen analysis, the saturation value of DO is a function of temperature, Figure 1.1 shows the variation of the saturation value with temperature.

b. Natural Background Quality - may vary depending on the characteristics of the land and its usage, and the rainfall and runoff patterns of the area. Such information may be available from historical data or river surveys, for dissolved oxygen deficit reasonable values for low, moderate and high are 0.5, 1.0 and 2.0 mg/l respectively.

The high value is indicative of highly organic and/or swampy areas while the lower value is associated with low organic mineral areas.

In the analysis discussed in the following section, any natural background water quality must be incorporated.

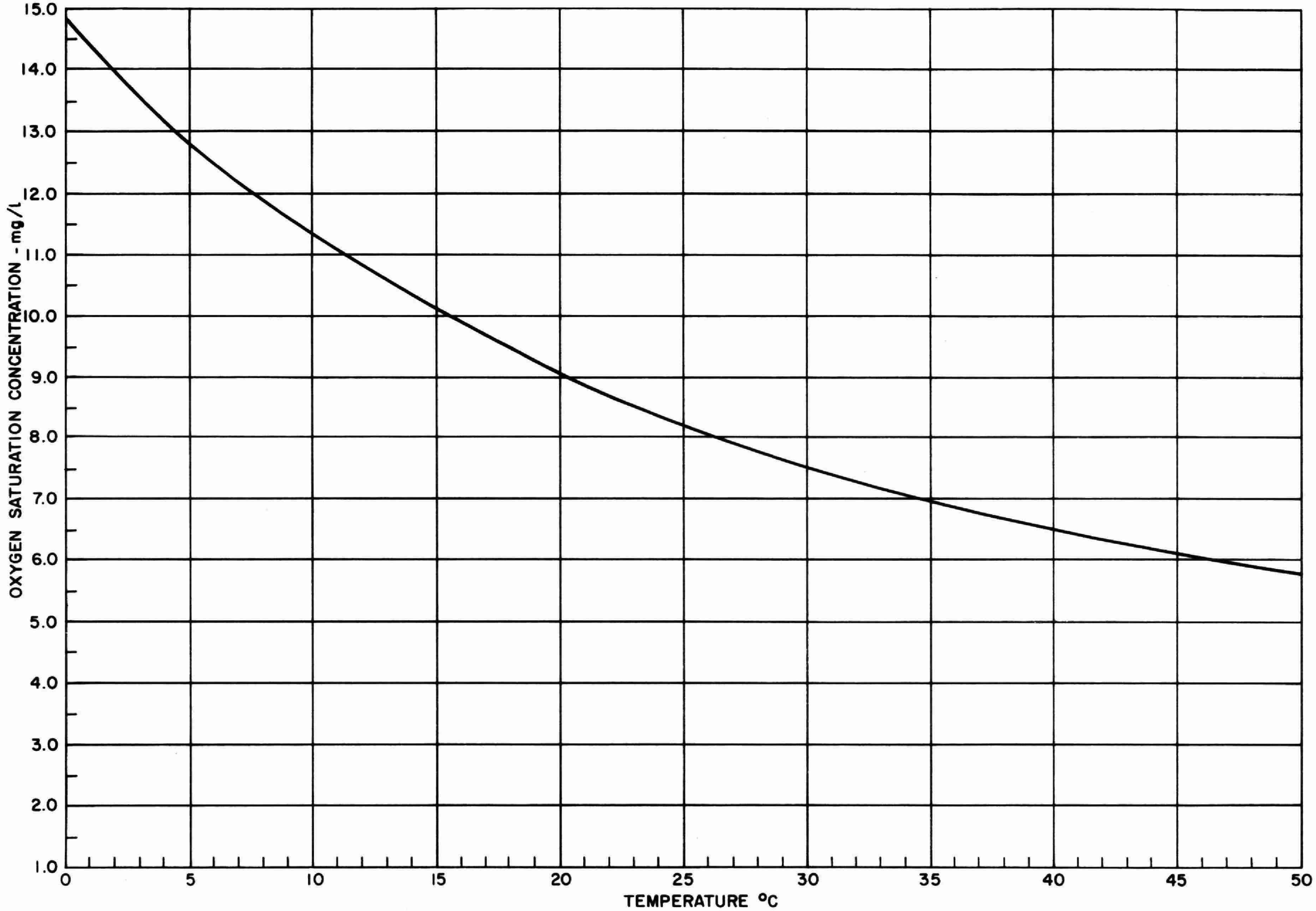

FIGURE 1.1. OXYGEN SATURATION -TEMPERATURE RELATIONSHIP

c. Freshwater Flow - provides not only dilution of the waste flow but also determines the velocity of the stream. The flow varies considerably from year to year. The low flow period usually occurs in summer-early fall and in conjuction with the still high temperature at that time of year, produce the most severe water quality conditions. Average annual flow and estimation of low flows can be obtained from an analysis of historical records and are usually expressed in cfs/sq. mi. or cfs units.

Stream flow data are published annually by the Ministry of the Environment in the Selected Streamflow Data for Ontario and by Environment Canada in the Surface Water Data, Ontario.

If the low flow data are not available, an estimate can be made by comparison with a nearby drainage basin of similar geophysical characteristics and adjusted to the drainage area of the stream in question.

The flow in the stream is obtained by multiplying the flow expressed in cubic feet per second per square mile of drainage area by the drainage area at the location of the waste water discharge. The total flow of the stream in cfs downstream from the point of discharge is therefore:

$$Q = f_5 \, DA + \text{waste Flow} \quad \ldots\ldots \quad 1.5$$

where: f_5 = cubic feet per second per square mile

DA = drainage area (sq. mi.)

II PRELIMINARY MODEL OF STREAMS AND RIVERS

1. OUTLINE

Water quality analysis of streams may be classified in accordance with the reactive nature of the constituents in wastewater namely, conservative or non-conservative.

a. Conservative Substance

Conservative substances may include essentially non-disappearing substances, e.g. dissolved solids, chlorides, and nutrients (total nitrogen and total phosphorus).

The maximum concentration (C) of this type of constituent is at the point of discharge, assuming a completely mixed system, and is the mass rate of waste discharge (W) divided by the total flow (Q):

$$C = \frac{W}{Q} \quad \ldots\ldots 2.1$$

For multiple sources, the total concentration in the stream is the arithmetic addition of the individual effects plus the background value, Figure 2.1. For slowly decaying substances (K[1] ≤ 0.2/day) it may be sufficiently accurate to add responses such as given by Equation 2.1 to indicate order of magnitude.

[1] *The reaction rate K, represents the rate which a substance builds up or die away and has units per time (T^{-1}). All K rates are to the base e.*

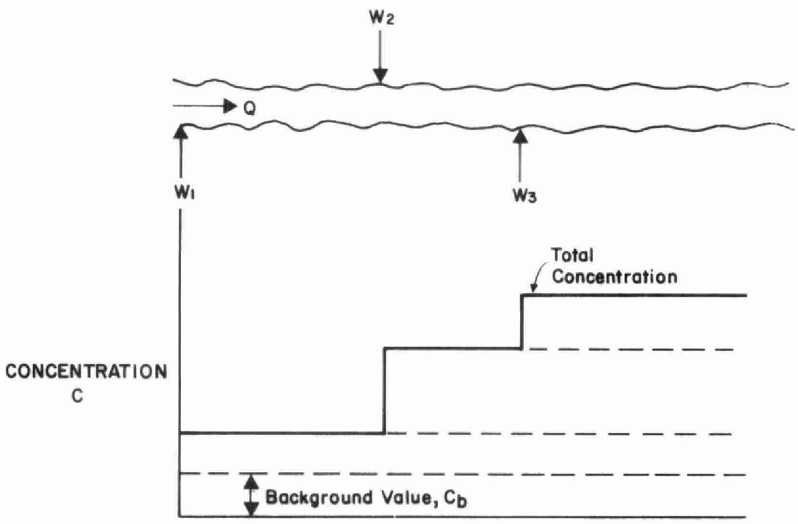

FIGURE 2.1 SUPERPOSITION OF MULTIPLE WASTE SOURCES OF CONSERVATIVE SUBSTANCES

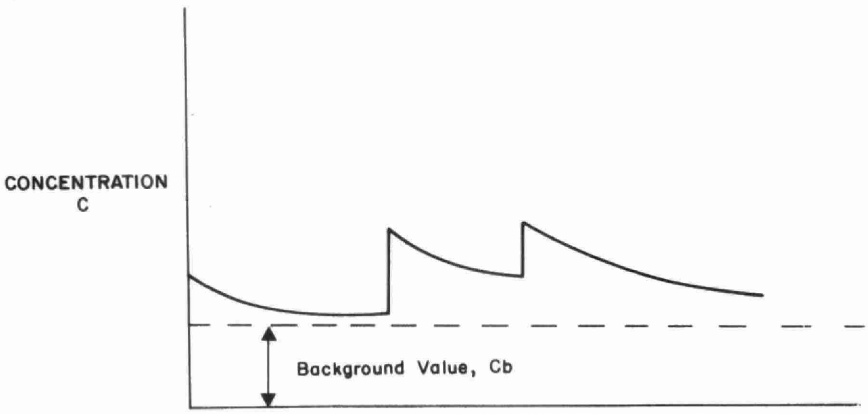

FIGURE 2.2 SUPERPOSITION OF MULTIPLE WASTE SOURCES OF NON-CONSERVATIVE SUBSTANCES

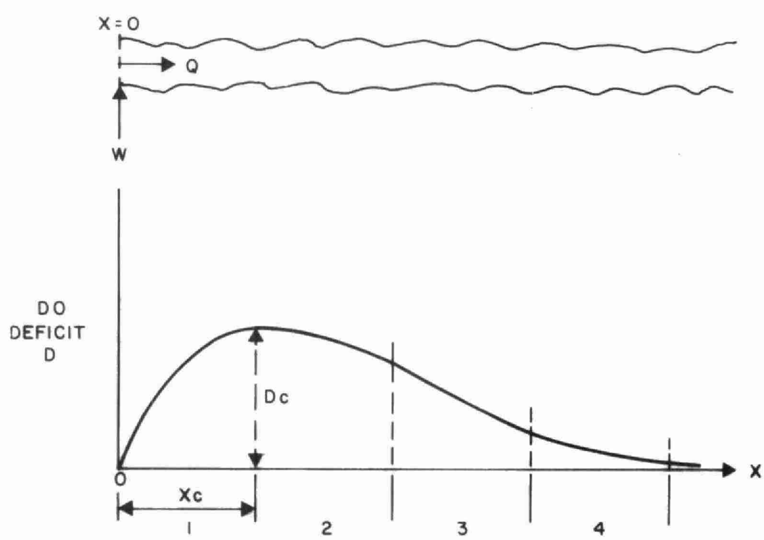

FIGURE 2.3 TYPICAL DO DEFICIT PROFILE

If this total concentration when compared to the water quality criterion is satisfactory, no further refinement is necessary. If the comparison is marginal it may be accepted since the analysis assumes a constant flow (Q) with no reactions taking place.

However, if the total concentration exceed the criterion it may be necessary to account for additonal inflow from groundwater or other sources entering along the length of the stream.

Should the concentration exceed the criterion subsequent to a detailed analysis of all sources of inflow to the stream, other methods would have to be considered for reducing the concentration further. These may include, reduction of the load at the source, flow augmentation or re-evaluation of the governing criterion.

b. Non-Conservative Substances

To account for substances which decay or undergo conversion by singular reaction e.g. bacteria concentration, radioactive matter, and oxygen demanding material, the following equation is adapted.

$$C = C_o e^{-\frac{K_x}{u}} \quad \ldots\ldots \quad 2.2$$

where:

C = Concentration at any location x

C_o = W/Q concentration in the stream at x=o

K = reaction coefficient (per day)

u = stream velocity

x = distance downstream

Ranges of values for reaction coefficients in freshwater streams for water temperature in the 20-25^oC range are:

Coliform Bacteria 1-3 per day

BOD 0.2-2.0 per day

Conversion to other temperatures can be made by:

$$K_T = K_{20} (1.047)^{T-20} \quad \ldots\ldots \quad 2.3$$

where, K_T is the reaction coefficient at temperature, T^oC and K_{20} is the reaction coefficient at 20^oC.

For multiple sources, the concentration profile is as shown in Figure 2.2.

c. Dissolved Oxygen Analysis

The concentration profile of dissolved oxygen downstream from a waste discharge is the result of a consecutive reaction. The first which is primarily the oxidative reaction of the residual organic matter, and the second which is the reaeration replacing the deficit caused by the first reaction. Consider a single source of waste water discharging at a rate of W into a stream with a fresh water flow of Q. The outfall is located at x=o downstream from which a typical dissolved oxygen deficit profile result, as shown in Figure 2.3.

The DO deficit (D) is given by the saturation value of oxygen (C_s), minus the dissolved oxygen (C) i.e.:

$$D = C_s - C \quad \ldots\ldots 2.4$$

The equation for the deficit profile is:

$$D = \frac{K_d\ L_o}{K_a - K_r}\left(e^{-K_r\frac{x}{\bar{u}}} - e^{-K_a\frac{x}{\bar{u}}}\right) + D_o\ e^{-K_a\frac{x}{\bar{u}}} \quad \ldots\ldots 2.5$$

where:

D = Dissolved oxygen deficit at a distance x from point of reference. (mg/l)

D_o = Initial dissolved oxygen deficit at point of reference. (mg/l)

u = Average stream velocity. (ft/day)

L_o = Ultimate BOD at point of reference. (mg/l)

Ka = Reaeration coefficient (day^{-1}) also expressed as K_2.

K_d = Deoxygenation coefficient. (day^{-1})

K_r = Coefficient of BOD removal. (day^{-1})

The Bod removal coefficient K_r, represent removal by deoxygenation and by settling, i.e. $K_r = K_d + K_s$. In many cases the settleable fraction is very small and can be neglected because the stream velocity prevents the organics from settling. Also depending on the waste source, e.g., effluent from an STP, the settleable organics would have been removed before the effluent enters the stream.

thus:

for $K_r = K_d$;

The magnitude and location of the maximum deficit, is given by:

$$D_c = \frac{K_d}{K_a} L_o \, e^{\frac{-K_d x_c}{u}} \quad .....2.6$$

$$x_c = \frac{u}{K_a - K_d} \ln \frac{K_a}{K_d} \quad ..... 2.7$$

where:

D_c = Maximum DO deficit. (mg/l)

and;

x_c = Distance to location of maximum deficit from point of reference. (ft.)

Substituting equation 2.7 into 2.6 and rearranging terms:

$$\frac{D_c}{L_o} = \Phi^{\frac{\Phi}{1 - \Phi}} \quad .....2.8$$

where:

$$\Phi = \frac{K_a}{K_d}$$

The dimensionless ratio Φ is known as the assimilation ration. A practical range of Φ is from 0.1 to 20 for which D_c/L_c values are shown in Figure 2.4.

Equation 2.8 forms the basi's for the dissolved oxygen response in streams due to a single waste source. This will be discussed further together with a detailed description of reaction coefficients and assimilation ratio Φ.

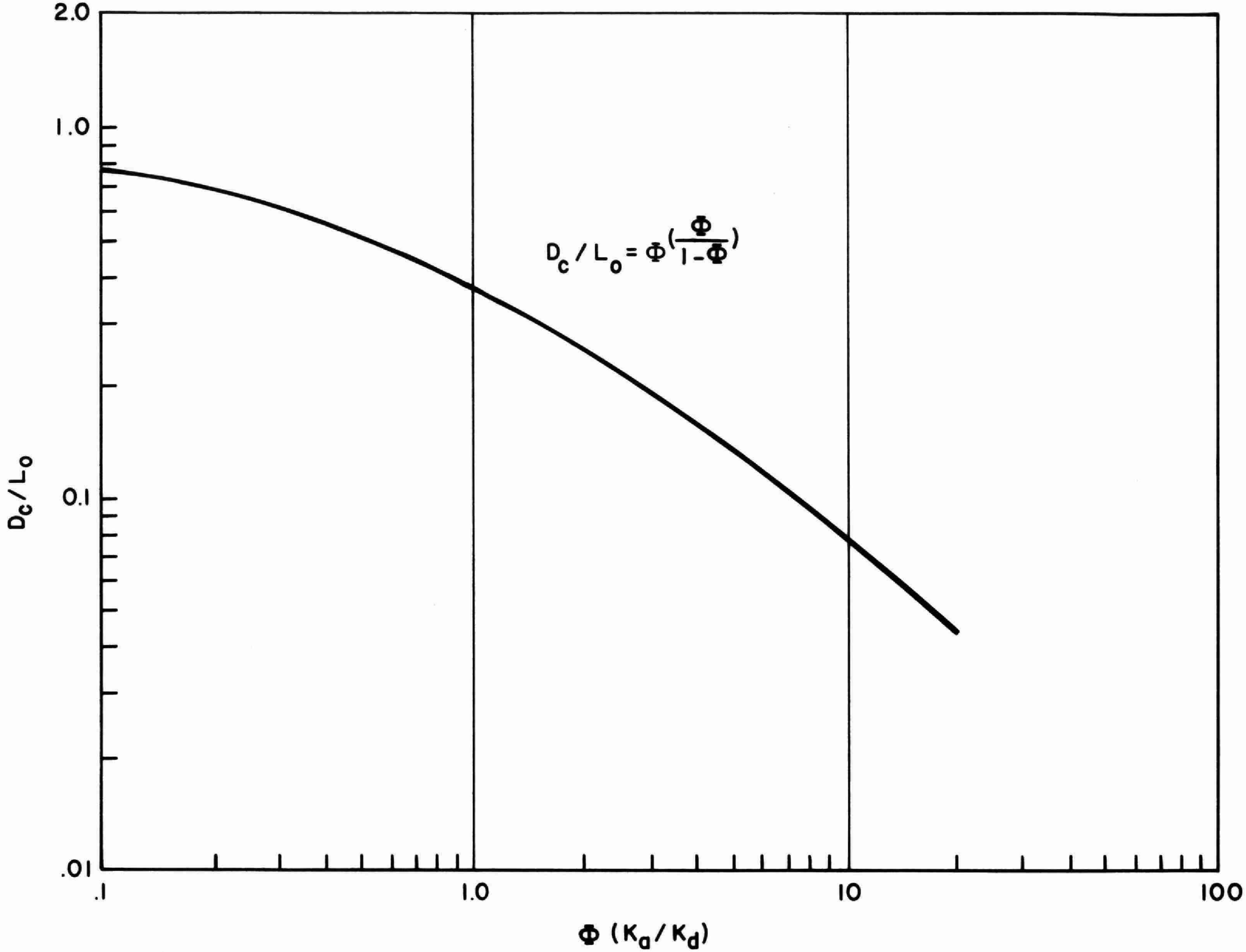

FIGURE 2.4 RATIO D_c/L_o AS A FUNCTION OF ASSIMILATION RATIO, Φ

2. Single Waste Source - Graphical Dissolved Oxygen Analysis

The estimation of the necessary treatment required to meet dissolved oxygen criterion for a single waste source in a stream can be summarized in a nomograph as given by chart A. This chart can be used to test the efficiency of several treatment levels in meeting dissolved oxygen criterion. The procedure can be reversed to estimate treatment efficiency required for a given minimum dissolved oxygen crtierion.

Figure A-1 represents the discrete levels of treatment considered. The solid lines represent the percentage removals shown in Table II. The broken lines represent removal efficiencies greater or less than those in Table II to allow for variable plant performances. Figure A-1 therefore permits estimation of the total oxygen demand in pounds/day that would be discharged from the given design population and treatment level.

Figure A-2 requires the total streamflow which includes the streamflow above the discharges plus the flow for the waste source itself, (Equation 1.5). Given the total oxygen demand from Figure A-1 and the streamflow, Figure A-2 is used to estimate the initial concentration of the total oxygen demand in mg/l resulting after dilution in the stream, (Equation 2.1). A zero upstream BOD concentration is assumed which will be accounted for in Figure A-4.

Figure A-3 incorporates the fundamental reaeration capacity of the stream using several different data levels. Information on the stream can be at one or all of the following levels:

a) Qualitative description, e.g., shallow, main drainage rivers, impounded rivers, etc.,

b) A measurement of depth of the river, a key variable,

c) Estimate of Φ, the ratio of the reaeration coefficient, K_a and the deoxygenation coefficient, K_d.

Given the previous description of the stream, the maximum DO deficit (mg/l) using Figure A-3 can be estimated. Note that a zero initial DO deficit has been assumed. Any "background" DO deficit is incorporated at the conclusion of the analysis. Figure A-3 is constructed from Equation 2.5, a discussion of which is given in the appendix.

Figure A-4 incorporates the variation of the DO saturation level with maximum water temperature (see Figure 1.1). With the maximum DO deficit and maximum water temperature, the minimum dissolved oxygen (mg/l) can be estimated. The "background" deficit is included at this point. In the absence of any data, it is recommended that the DO background deficit of 1.0 mg/l be considered as a minimum level.

A constant background DO deficit is incorporated for two reasons:

a) computational simplicity and,

b) existance of other sources and sinks of dissolved oxygen.

The theory indicates that an initial DO deficit decays exponentially at a rate given by the reaeration rate and stream velocity. To allow for the existence of other phenomena which affect DO, including benthal oxygen demanding material, algal photosynthesis and respiration, incremental additions of oxygen demanding loads from agricultural and urban drainage, among others, it was desirable to incorporate all these effects in a single constant background DO deficit.

The procedure described above provides a first estimate of the minimum dissolved oxygen which is then compared to the set criterion. If the dissolved oxygen for the given level of treatment is less than the criterion, the procedure can be reversed by starting at the required DO and continuing through Figures A-4, A-3, and A-2 using the same water temperature, stream reaeration capcity and total streamflow. One now enters Figure A-1 with the required total oxygen demand mass discharge. For the fixed design population, the next highest level of treatment is chosen which will equate or exceed the required pounds/day discharge.

Example 1:

A conventional secondary sewage treatment plant with phosphorus removal to serve an ultimate population of 150,000 is to be located at a point X on river Y. What will be the minimum dissolved oxygen level measured downstream as a result of the treated waste discharge?

Procedure:

a) Basic information required:

1. Plant size - the town is typical of Southern Ontario municipalities with a good mix of industry, commerce, apartment dwellings and individual houses. Per capita sewage flow selected is 150 gallons per day.

2. Low Flow - river Y has a continuous recording flow gauge near its mouth. The summer low flow (7Q20) is calculated and the results extrapolated on an drainage area ratio to point X. Therefore, calculated low flow is 85 cfs.

3. From water quality monitoring records, the maximum water temperature is 25^{o}C and the background dissolved oxygen deficit in mid-summer is 1 mg/l.

4. A field trip was taken and the river was observed from several vantage point downstream from point X. Based on field observation, a mean depth of 7 feet was selected.

Summary of Basic Information

Design Population	-	150,000 persons
Treatment type	-	Secondary
Per capita waste flow	-	150 gallons/day
Calculated drought flow	-	85 cfs
Maximum water temperature	-	25^oC
Mean depth of river	-	7 feet
Upstream DO deficit	-	1.0 mg/l

Total flow calculation:

River flow 85

Sewage
~~River~~ flow-150 x 150,000 x 1.86 x 10^{-6} = 42

Total = 127 cfs

b) Graphical solution: (see Figure 2.5)

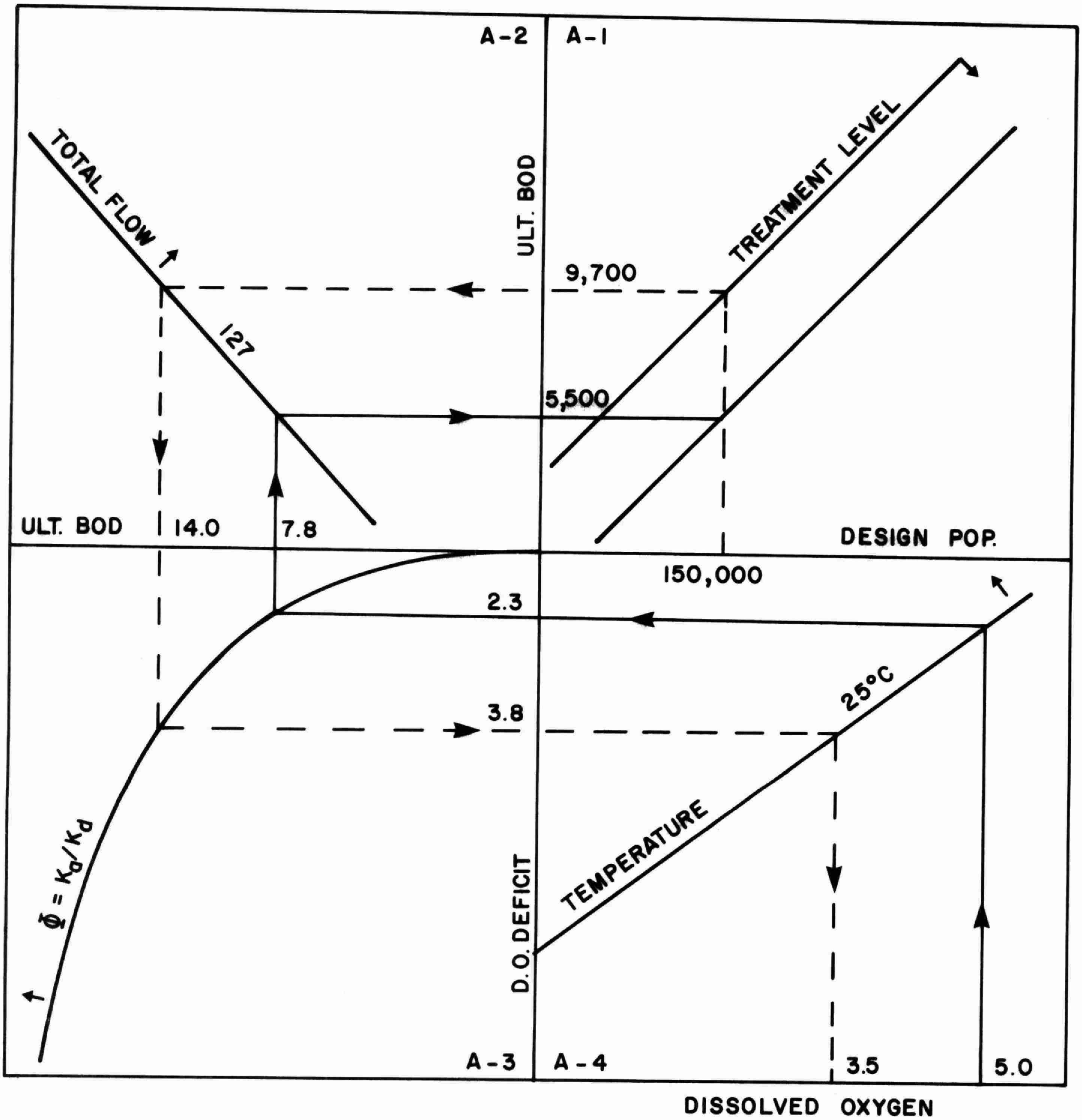

FIGURE 2.5 EXAMPLE I AND 2.

Enter Chart at:

Figure A-1, design population of 150,000 with secondary treatment gives an effluent load of 9,700 lb/day ultimate BOD.

Figure A-2, drought flow of 127 cfs and effluent load of 9,700 lb/day ultimate BOD gives upstream oxygen demand concentration of 14 mg/l.

Figure A-3, for an intermediate channel (7 feet. approximately) maximum DO deficit is 3.8 mg/l.

Figure A-4, at a temperature of 25°C, assuming a background deficit of 1.0 mg/l gives a minimum dissolved oxygen of 3.5 mg/l.

Example 2:

Given the same information as in example 1, determine the waste loading and treatment level required to maintain a dissolved oxygen level of 5.0 mg/l in the river.

Procedure:

Enter Chart at:

Figure A-4, for a minimum DO of 5.0 mg/l with a 1.0 mg/l background deficit and 25°C, the, maximum allowable deficit is 2.3 mg/l.

Figure A-3, for an intermediate channel, the allowable instream ultimate BOD concentration is 7.8 mg/l.

Figure A-2, for a drought flow of 127 cfs, the allowable treated discharge is 5,500 lb/day ultimate BOD.

Figure A-1, for a 5,500 lb/day discharge and a design population of 150,000 the treatment level will have to be bordering the advance level to achieve the 5.0 mg/l minimum DO in the stream.

Example 3:

Estimate the streamflow necessary for discharging a seasonal lagoon while maintaining a minimum DO of 5.0 mg/l, given the following information:

Population	1000
Per capita flow	100 gals.
Retention time	180 days
Lagoon size	13.3 ac. by 5 feet depth
Lagoon effluent	25 mg/l BOD_5, k = 0.25
Stream	Upstream feeder, depth approx. 4 feet

Procedure:

Sewage flow	1000 x 100 = 100,000 gals/day
	= 0.186 cfs

For a continuous discharge over three days, flow rate is:

$$\frac{13.3 \times 43560 \times 5}{3 \times 24 \times 3600} = 11.2 \text{ cfs}$$

Waste Load:

$$UBOD = \frac{BOD_5}{(1 - e^{-kt})}$$

$$UBOD = \frac{25}{(1 - e^{-0.25 \times 5})} = 35 \text{ mg/l}$$

thus waste load = 11.2 x 5.4 x 35 = 2120 lb/day

Enter Chart at:

Figure A-4, for minimum DO of 5.0 mg/l with a 1.0 mg/l background deficit and at 25°C, the maximum allowable deficit is 2.3 mg/l.

Figure A-3, for an upstream feeder, the allowable instream ultimate BOD concentration is 13.0 mg/l.

Figure A-2, for a waste load of ~~1815~~ 2120 lb/day and allowable BOD concentration of 13.0 mg/l, the total flow is 31 cfs.

Similarly :

Days	cfs	Load Lb/Day	Total Flow	Stream Flow
3	11.2	2120	31	19.8
5	6.2	1175	15	8.8
7	4.8	910	12	7.2
10	3.4	645	9.4	6.0

The rate of discharge and duration can then be selected based on the streamflow. By examining past flow records, a suitable period can be selected for partial or complete discharge of the lagoon.

NOTES

APPENDIX

REACTION COEFFICIENTS

1. Aeration Coefficient

The transfer of oxygen from the atmosphere to water is essentially a surface controlled phenomenon. The relationship between the surface transfer coefficient K_L and the volumetric coefficient K_a is:

$$K_a = K_L \frac{A}{V} = \frac{K_L}{H} \quad \ldots\ldots \quad \text{A-1}$$

where: A = surface area of river reach

V = volume at river reach

H = average depth

It has been shown that these coefficients are directly proportional to the velocity of the stream, raised to some power "a" and inversely proportional to the average depth of the stream to a power "b" namely, $\left(\frac{D_L V}{H^{3/2}}\right)^{\frac{1}{2}}$. A plot of the transfer coefficient verses the average depth of the average depth of the stream is shown in Figure 1 for various velocity ranges. Figure II is a plot of K_a (evaluated from Equation A-1), verses average depth for three velocity ranges. The three curves are indicative of the range of water surface conditons, and stream bed characteristics.

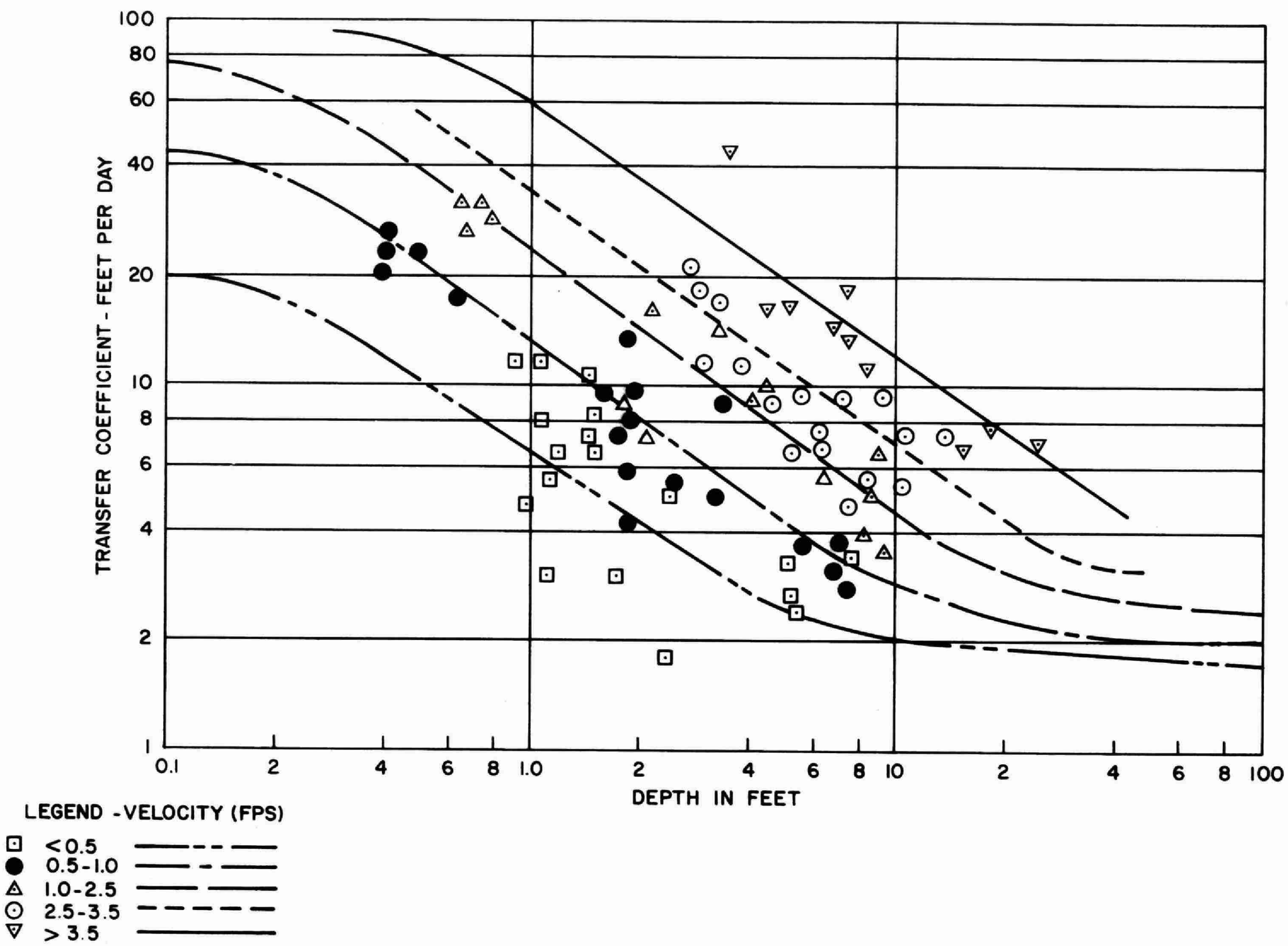

FIGURE I. TRANSFER COEFFICIENT (K_L) AS A FUNCTION OF DEPTH
(From Hydroscience Inc. 1971)

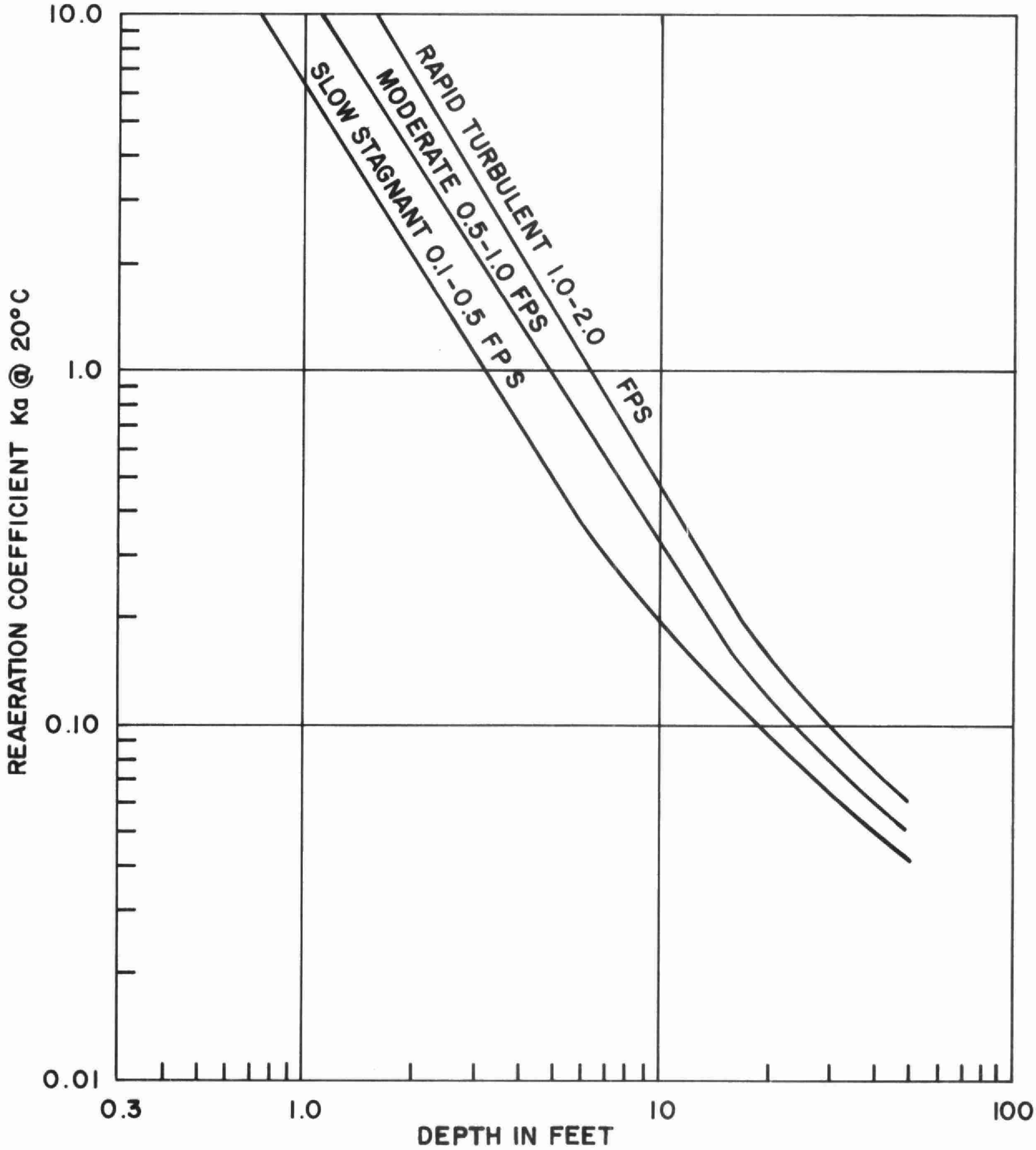

FIGURE II. REAERATION COEFFICIENT (Ka) AS A FUNCTION OF DEPTH
(From Hydroscience Inc. 1971)

2. Deaeration Coefficient

A similar correlation has been developed for the deaeration or deoxygenation coefficient K_d and average depth H. This correlation is based on the fact that the greater the wetted perimeter to cross-section, which is equivalent to small depth, the greater the contact with the biological forms on the stream bed. Figure III is a plot of K_d verses average depth based on data surveys.

The upper line represents a stable, rocky bed with benthal communities, whilst the lower line represent a unstable bed with sparce benthal communities.

In addition, the nature of the residual organic matter in the effluent from the treatment plant is a determining factor. The lower limit represents highly treated, well oxidized effluents with efficient secondary sedimentation of the active bacterial populations. The residues are therefore highly stable organically with low rates of oxidation. The upper limit is representative of waste with more residual organic matter, some of which is capable of relatively rapid oxidation.

3. Assimilation Ratio

The assimilation ratio Φ (K_a/K_d) is plotted in Figure IV verses the average depth, the correlation being developed directly from those in Figures II and III. The heavy solid line represents the average case. If actual

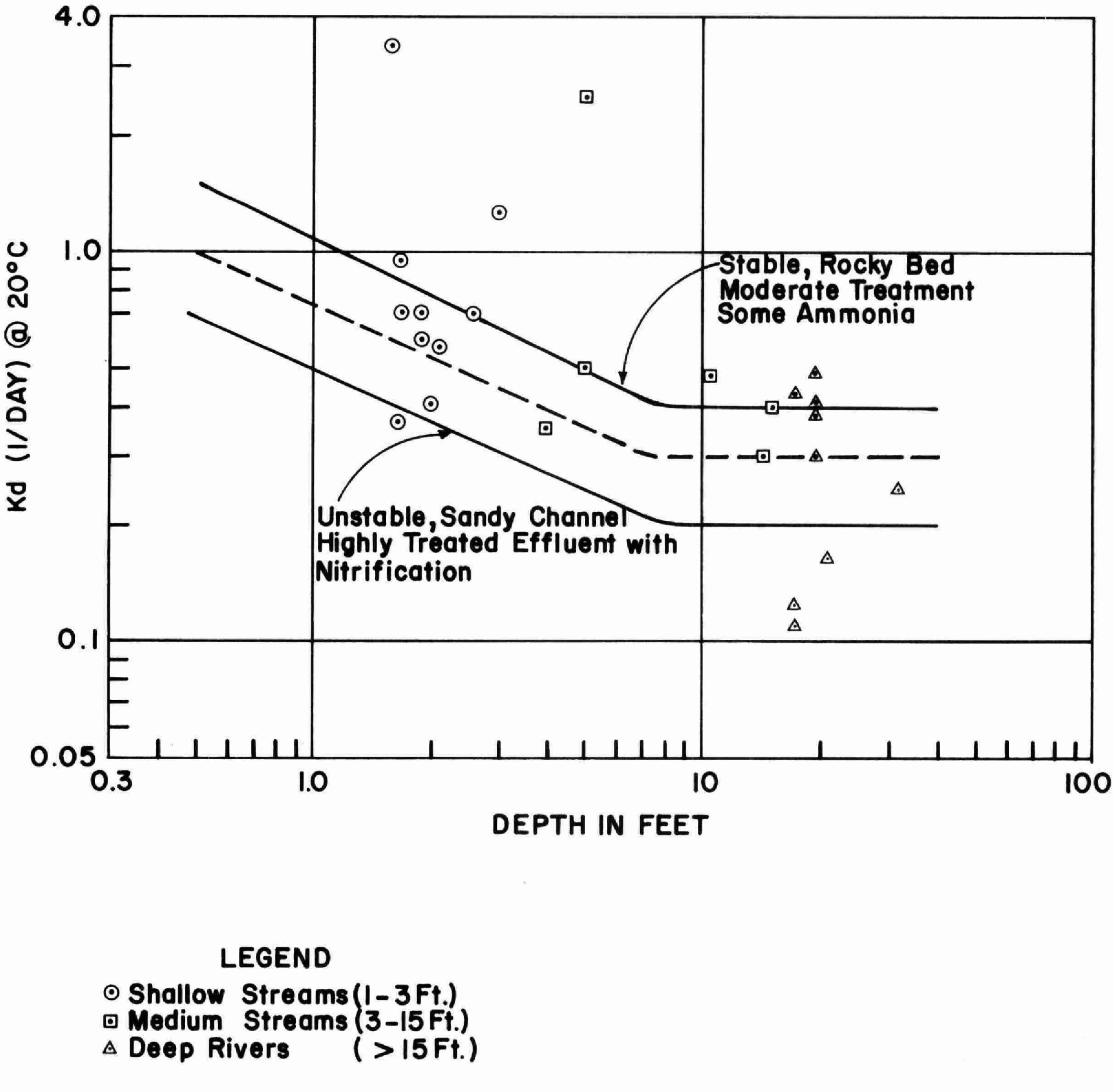

FIGURE III. DEOXYGENATION COEFFICIENT (Kd) AS A FUNCTION OF DEPTH
(From Hydroscience Inc. 1971)

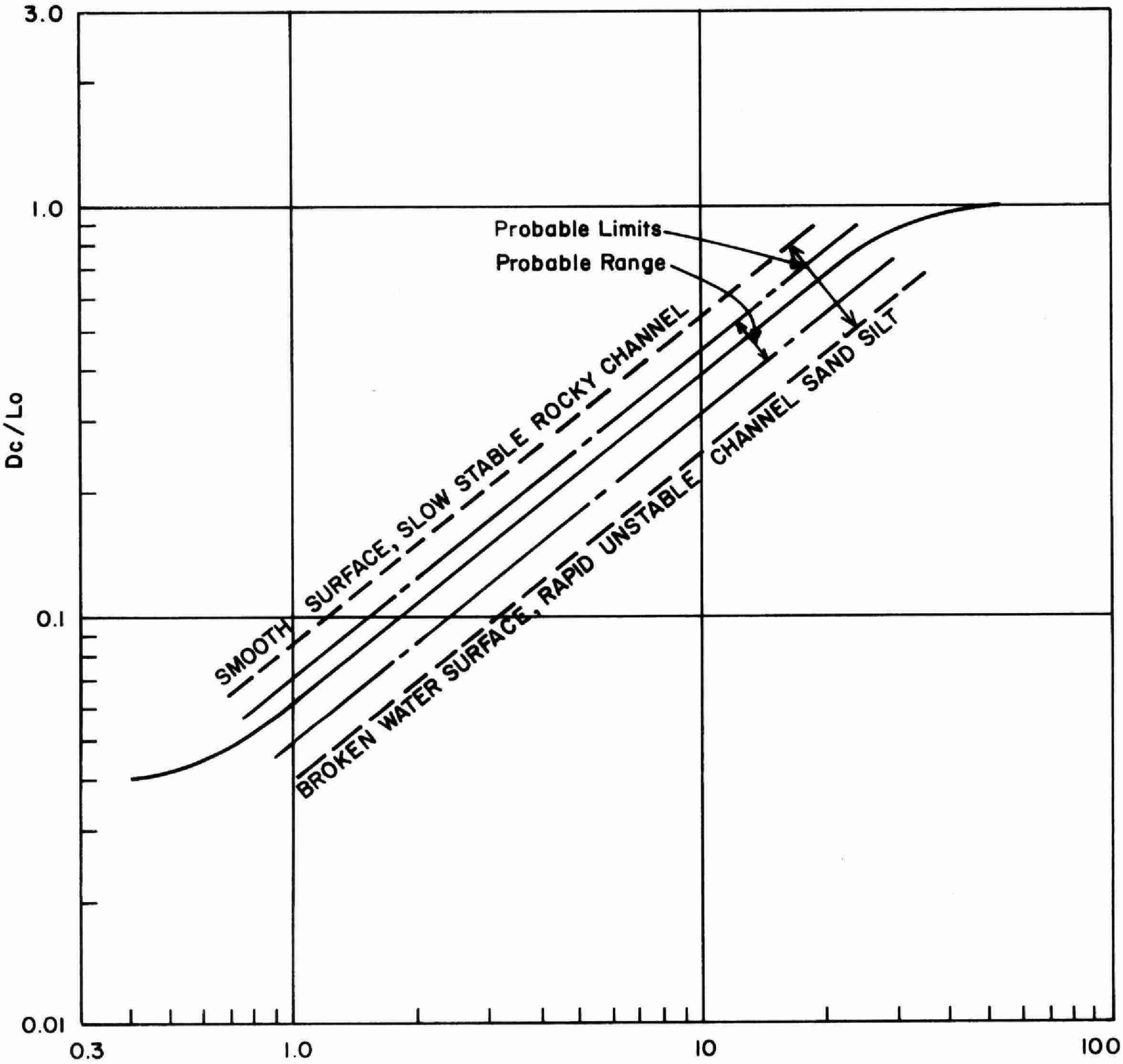

FIGURE V. RATIO Dc/Lo AS A FUNCTION OF DEPTH
(From Hydroscience Inc. 1971)

data are available from stream surveys to determine Φ, this information should obviously be employed in the DO analysis. If no data are available to estimate the individual coefficients, the ratio may be estimated simply from the depth. Further information on the nature of the stream and the anticipated treatment enables further refinement within the range indicated.

The final step is the conversion of the ratio Φ, to (D_c/L_0), indicated in Figure 3 of the main text. The relation between D_c/L_0 and the average depth, H, with limits as indicated, is shown in Figure V.

The relation presented in Figure V, is the basis of the nomographs presented in the stream analysis section.

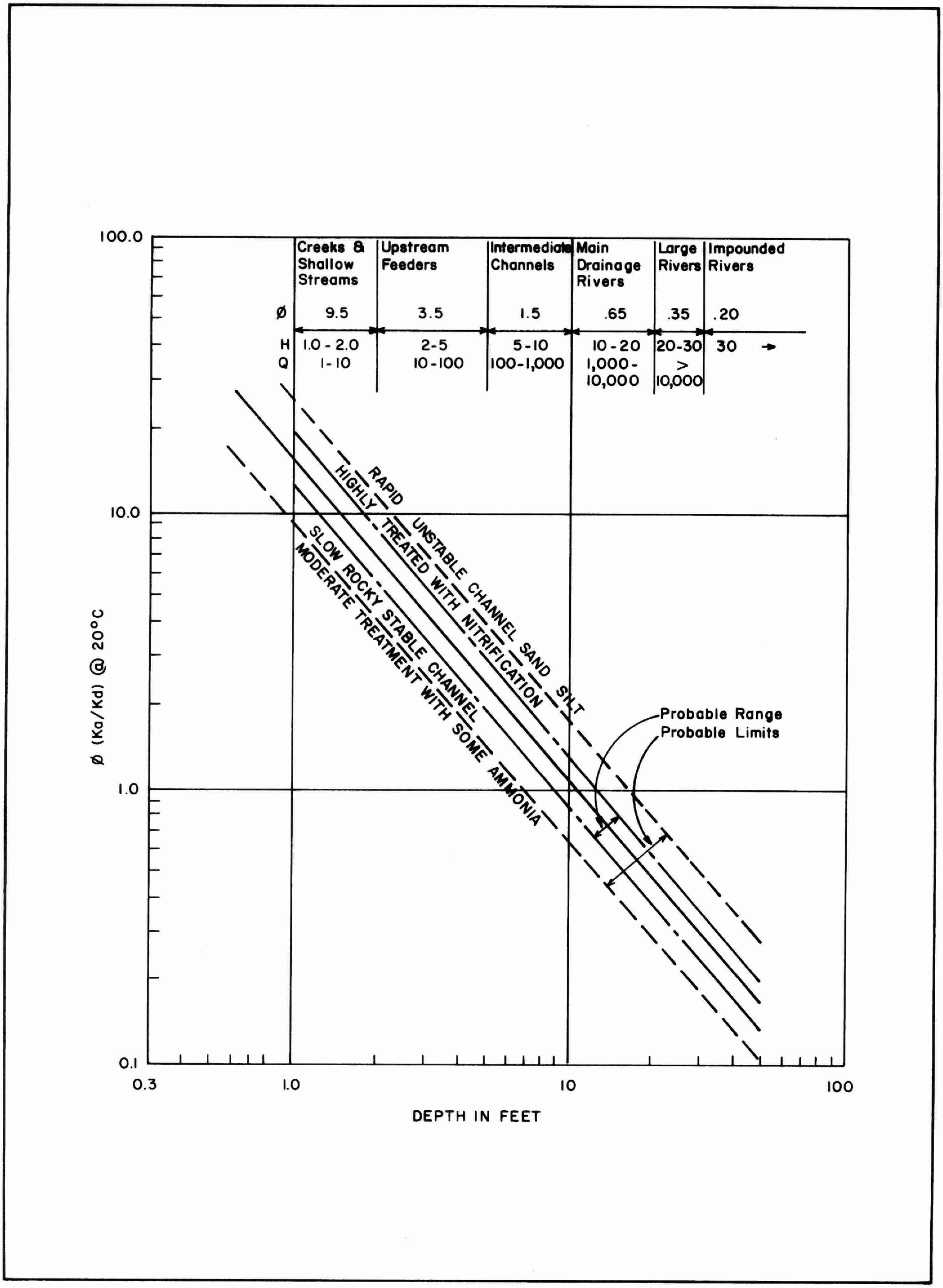

FIGURE IV. ASSIMILATION RATIO (Ø) AS A FUNCTION OF DEPTH
(From Hydroscience Inc. 1971)

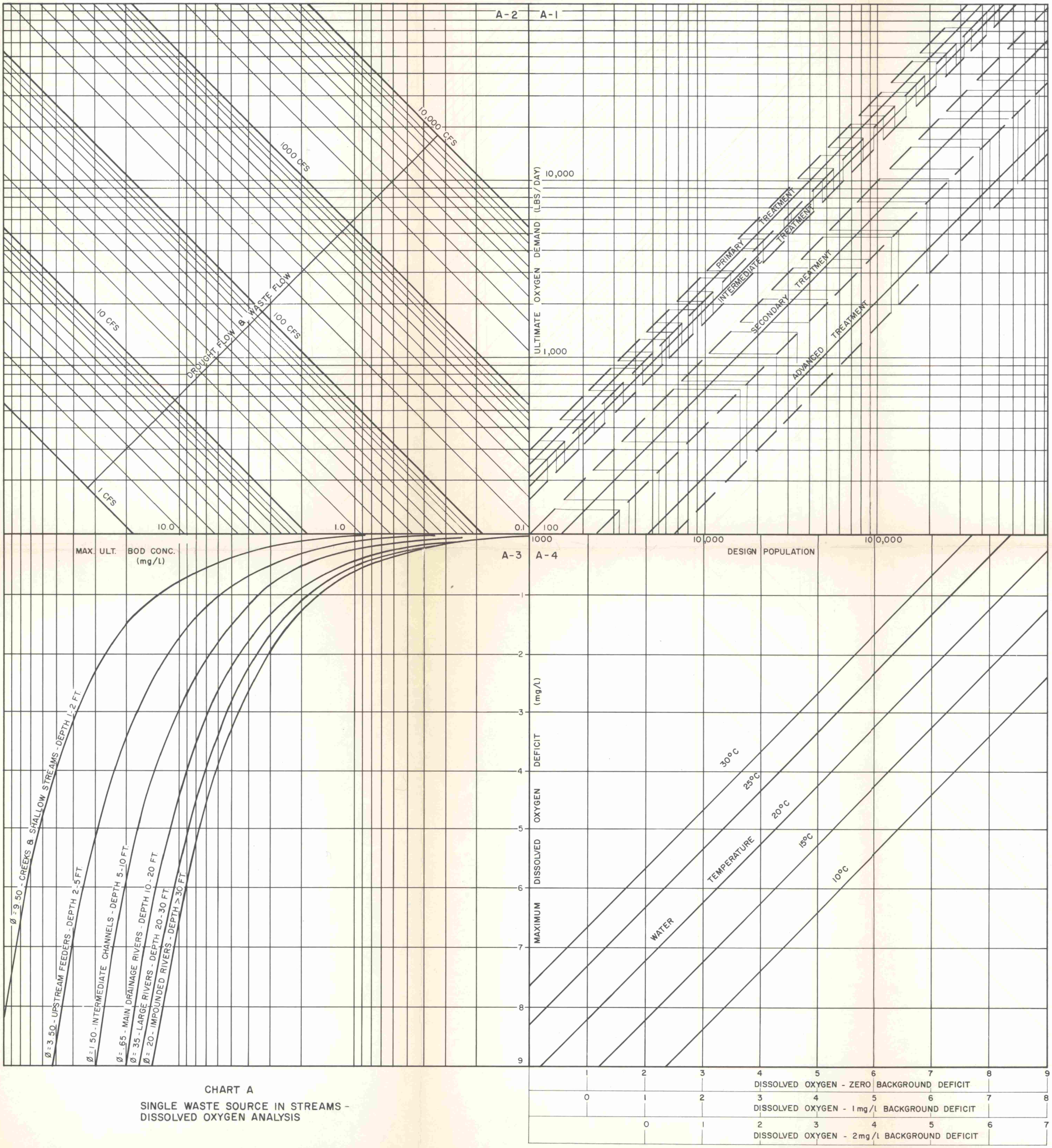

CHART A

SINGLE WASTE SOURCE IN STREAMS - DISSOLVED OXYGEN ANALYSIS